CLAIMS

1. A method of forming a titanium-based mixed-metal product, comprising combining a mixture of titanium halide and at least one metal halide with a reducing agent to produce a mixed-metal product comprising titanium and at least one metal corresponding to the at least one metal of the at least one metal halide; wherein,

the at least one metal of the at least one metal halide is selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, Yb and Zr;

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one metal.

2. The method of claim 1 wherein the mixed-metal product comprises greater than 0.1% of the at least one metal.

3. The method of claim 1 wherein the mixed-metal product comprises greater than 0.5% of the at least one metal.

4. The method of claim 1 wherein the at least one metal is only one metal.

5. The method of claim 1 wherein the at least one metal is two metals.

6. The method of claim 1 wherein the at least one metal comprises Zr.

7. The method of claim 1 wherein the at least one metal comprises Hf.

8. A method of forming a titanium-based mixed-metal product, comprising electrolytically depositing a mixed-metal product comprising a mixture of titanium and at least one other metal, the at least one other metal being selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, Yb and Zr; wherein

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one other metal.

9. The method of claim 8 wherein the mixed-metal product comprises greater than 0.1% of the at least one other metal.

10. The method of claim 8 wherein the mixed-metal product comprises greater than 0.5% of the at least one other metal.

11. The method of claim 8 wherein the at least one other metal is only one other metal.

12. The method of claim 8 wherein the at least one other metal is two other metals.

13. The method of claim 8 wherein the at least one metal comprises Zr.

14. The method of claim 8 wherein the at least one metal comprises Hf.

15. A method of forming a titanium-based mixed-metal product, comprising:

providing a mixture of titanium and least one other metal in a reaction apparatus with iodine gas and a heated substrate; the at least one other metal being selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, Yb and Zr;

reacting the titanium and the at least one other metal with the iodine gas to form titanium iodide and an iodide of the at least one other metal;

transferring the titanium iodide and the iodide of the at least one other metal to the heated substrate, and utilizing heat from the substrate to decompose the iodides and produce a mixed-metal product comprising titanium and the at least one other metal; wherein

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one other metal.

16. The method of claim 15 wherein the mixed-metal product comprises greater than 0.1% of the at least one other metal.

17. The method of claim 15 wherein the mixed-metal product comprises greater than 0.5% of the at least one other metal.

18. The method of claim 15 wherein the at least one other metal is only one other metal.

19. The method of claim 15 wherein the at least one other metal is two other metals.

20. The method of claim 15 wherein the at least one metal comprises Zr.

21. The method of claim 15 wherein the at least one metal comprises Hf.

22. A method of forming a zirconium-based mixed-metal product, comprising combining a mixture of zirconium halide and at least one metal halide with a reducing agent to produce a mixed-metal product comprising zirconium and at least one metal corresponding to the at least one metal of the at least one metal halide; wherein,

the at least one metal of the at least one metal halide is selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, Ti, V, W, Y, and Yb;

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one metal.

23. The method of claim 22 wherein the mixed-metal product comprises greater than 0.1% of the at least one metal.

24. The method of claim 22 wherein the mixed-metal product comprises greater than 0.5% of the at least one metal.

25. The method of claim 22 wherein the at least one metal is only one metal.

26. The method of claim 22 wherein the at least one metal is two metals.

27. The method of claim 22 wherein the at least one metal comprises Ti.

28. The method of claim 22 wherein the at least one metal comprises Hf.

29. A method of forming a zirconium-based mixed-metal product, comprising electrolytically depositing a mixed-metal product comprising a mixture of zirconium and at least one other metal, the at least one other metal being selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, Ti, V, W, Y, and Yb; wherein

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one other metal.

30. The method of claim 29 wherein the mixed-metal product comprises greater than 0.1% of the at least one other metal.

31. The method of claim 29 wherein the mixed-metal product comprises greater than 0.5% of the at least one other metal.

32. The method of claim 29 wherein the at least one other metal is only one other metal.

33. The method of claim 29 wherein the at least one other metal is two other metals.

34. The method of claim 29 wherein the at least one metal comprises Ti.

35. The method of claim 29 wherein the at least one metal comprises Hf.

36. A method of forming a zirconium-based mixed-metal product, comprising:

providing a mixture of zirconium and least one other metal in a reaction apparatus with iodine gas and a heated substrate; the at least one other metal being selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, Ti, V, W, Y, and Yb;

reacting the zirconium and the at least one other metal with the iodine gas to form zirconium iodide and an iodide of the at least one other metal;

transferring the zirconium iodide and the iodide of the at least one other metal to the heated substrate, and utilizing heat from the substrate to decompose the iodides and produce a mixed-metal product comprising zirconium and the at least one other metal; wherein

the mixed-metal product is at least 99.95% pure; and

the mixed-metal product comprises greater than 0.05% of the at least one other metal.

37. The method of claim 36 wherein the mixed-metal product comprises greater than 0.1% of the at least one other metal.

38. The method of claim 36 wherein the mixed-metal product comprises greater than 0.5% of the at least one other metal.

39. The method of claim 36 wherein the at least one other metal is only one other metal.

40. The method of claim 36 wherein the at least one other metal is two other metals.

41. The method of claim 36 wherein the at least one metal comprises Ti.

42. The method of claim 36 wherein the at least one metal comprises Hf.

43. A method of forming a titanium-based mixed-metal ingot, comprising:

combining a mixture of titanium halide and one or more other metal halides with a reducing agent to produce a mixed-metal product; wherein the one or more other metal halides are selected from the group consisting of halides of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, Yb and Zr;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot; the ingot comprising titanium and one or more other metals; the one or more other metals corresponding to one or more of the other metals of the one or more metal halides; the titanium being the majority element of the ingot; the ingot having a purity of titanium and the one or more other metals of at least 99.95%.

44. The method of claim 43 wherein the titanium halide is a titanium chloride, and wherein the other metal halides are metal chlorides.

45. The method of claim 43 wherein the ingot has a purity of the titanium and the one or more other metals of at least 99.995%.

46. The method of claim 43 wherein the ingot has a purity of the titanium and the one or more other metals of at least 99.9995%.

47. The method of claim 43 wherein the one or more other metals comprise zirconium.

48. The method of claim 43 wherein the one or more other metals is only one other metal and consists of zirconium.

49. The method of claim 43 further comprising forming a sputtering target from the ingot.

50. A method of forming a zirconium-based mixed-metal ingot, comprising:

combining a mixture of zirconium halide and one or more other metal halides with a reducing agent to produce a mixed-metal product;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot, the ingot comprising zirconium and one or more other metals corresponding to the one or more other metals of the one or more metal halides, the zirconium being the majority element of the ingot; the ingot having a purity of zirconium and the one or more other metals of at least 99.95%.

51. The method of claim 50 wherein the zirconium halide is a zirconium chloride, and wherein the other metal halides are metal chlorides.

52. The method of claim 50 wherein the ingot has a purity of the zirconium and the one or more other metals of at least 99.995%.

53. The method of claim 50 wherein the ingot has a purity of the zirconium and the one or more other metals of at least 99.9995%.

54. The method of claim 50 wherein the one or more other metals are selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, Ti, V, W, Y, and Yb.

55. The method of claim 50 wherein the one or more other metals comprise titanium.

56. The method of claim 50 wherein the one or more other metals is only one other metal and consists of titanium.

57. The method of claim 50 wherein the reducing agent is selected from the group consisting of sodium metal and magnesium metal.

58. The method of claim 50 further comprising forming a sputtering target from the ingot.

59. A method of forming a titanium-based mixed-metal ingot, comprising:

electrolytically depositing a mixture of titanium and at least one other metal, the deposited mixture being a mixed-metal product;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot, the ingot comprising the titanium and the at least one other metal, the titanium being the majority element of the ingot; the ingot having a purity of titanium and the at least one other metal of at least 99.95%.

60. The method of claim 59 wherein the at least one other metal that is deposited has a deposition reduction potential within ± 0.7 volts of the reduction potential for conversion of Ti^{2+} to elemental Ti.

61. The method of claim 59 wherein the at least one other metal that is deposited has a deposition reduction potential within ± 0.5 volts of the reduction potential for conversion of Ti^{2+} to elemental Ti.

62. The method of claim 59 wherein the at least one other metal that is deposited includes Zr.

63. The method of claim 59 wherein the at least one other metal that is deposited is only one other metal and consists of Zr.

64. The method of claim 59 further comprising:

combining a mixture of titanium halide and metal halide with a reducing agent to produce a mixed-metal feedstock, the metal halide comprising the at least one other metal; and

wherein the electrolytically depositing utilizes the mixed-metal feedstock as an anode and comprises transferring titanium and the at least one other metal from the anode to a cathode whereupon the titanium and at least one other metal are deposited as the mixed-metal product.

65. A method of forming a zirconium-based mixed-metal ingot, comprising:

electrolytically depositing a mixture of zirconium and at least one other metal, the deposited mixture being a mixed-metal product;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot, the ingot comprising the zirconium and the at least one other metal, the zirconium being the majority element of the ingot; the ingot having a purity of zirconium and the at least one other metal of at least 99.95%.

66. The method of claim 65 wherein the at least one other metal that is deposited has a deposition reduction potential within ± 0.7 volts of the reduction potential for conversion of Zr^{2+} to elemental Zr.

67. The method of claim 65 wherein the at least one other metal that is deposited has a deposition reduction potential within ± 0.5 volts of the reduction potential for conversion of Zr^{2+} to elemental Zr.

68. The method of claim 65 wherein the at least one other metal that is deposited includes Ti.

69. The method of claim 65 wherein the at least one other metal that is deposited is only one other metal and consists of Ti.

70. The method of claim 65 further comprising:

combining a mixture of zirconium halide and metal halide with a reducing agent to produce a mixed-metal feedstock, the metal halide comprising the at least one other metal; and

wherein the electrolytically depositing utilizes the mixed-metal feedstock as an anode and comprises transferring zirconium and the at least one other metal from the anode to a cathode whereupon the zirconium and at least one other metal are deposited as the mixed-metal product.

71. A method of forming a titanium-based mixed-metal ingot, comprising:

providing a mixture of titanium and least one other metal in a reaction apparatus with iodine gas and a heated substrate;

reacting the titanium and the at least one other metal with the iodine gas to form titanium iodide and an iodide of the at least one other metal;

transferring the titanium iodide and the iodide of the at least one other metal to the heated substrate, and utilizing heat from the substrate to decompose the iodides and produce a mixed-metal product, the mixed-metal product comprising titanium and the at least one other metal;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot, the ingot comprising the titanium and the at least one other metal, the titanium being the majority element of the ingot; the ingot having a purity of titanium and the at least one other metal of at least 99.95%.

72. The method of claim 71 wherein the at least one other metal is selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, Yb and Zr.

73. The method of claim 71 wherein the at least one other metal comprises zirconium.

74. The method of claim 71 wherein the at least one other metal is only one other metal and consists of zirconium.

75. The method of claim 71 further comprising forming the mixture of titanium and the at least one other metal by combining a mixture of titanium halide and metal halide with a reducing agent to produce the mixture, the metal halide comprising the at least one other metal.

76. The method of claim 71 further comprising forming the mixture of titanium and the at least one other metal by electrolytically depositing the mixture of titanium and the at least one other metal.

77. The method of claim 76 further comprising:

combining a mixture of titanium halide and metal halide with a reducing agent to produce a mixed-metal feedstock, the metal halide comprising the at least one other metal; and

wherein the electrolytically depositing utilizes the mixed-metal feedstock as an anode and comprises transferring titanium and the at least one other metal from the anode to a cathode whereupon the titanium and at least one other metal are deposited as the mixture of titanium and the at least one other metal.

78. A method of forming a zirconium-based mixed-metal ingot, comprising:

providing a mixture of zirconium and least one other metal in a reaction apparatus with iodine gas and a heated substrate;

reacting the zirconium and the at least one other metal with the iodine gas to form zirconium iodide and an iodide of the at least one other metal;

transferring the zirconium iodide and the iodide of the at least one other metal to the heated substrate, and utilizing heat from the substrate to decompose the iodides and produce a mixed-metal product, the mixed-metal product comprising zirconium and the at least one other metal;

melting the mixed-metal product to form a molten mixed-metal material; and

cooling the molten mixed-metal material into a mixed-metal ingot, the ingot comprising the zirconium and the at least one other metal, the zirconium being the majority element of the ingot; the ingot having a purity of zirconium and the at least one other metal of at least 99.95%.

79. The method of claim 78 wherein the at least one other metal is selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, Ti, V, W, Y, and Yb.

80. The method of claim 78 wherein the at least one other metal comprises titanium.

81. The method of claim 78 wherein the at least one other metal is only one other metal and consists of titanium.

82. The method of claim 78 further comprising forming the mixture of zirconium and the at least one other metal by combining a mixture of zirconium halide and metal halide with a reducing agent to produce the mixture, the metal halide comprising the at least one other metal.

83. The method of claim 78 further comprising forming the mixture of zirconium and the at least one other metal by electrolytically depositing the mixture of zirconium and the at least one other metal.

84. The method of claim 83 further comprising:

combining a mixture of zirconium halide and metal halide with a reducing agent to produce a mixed-metal feedstock, the metal halide comprising the at least one other metal; and

wherein the electrolytically depositing utilizes the mixed-metal feedstock as an anode and comprises transferring zirconium and the at least one other metal from the anode to a cathode whereupon the zirconium and at least one other metal are deposited as the mixture of zirconium and the at least one other metal.

85. A sputtering target comprising Zr and one or more elements selected from the group consisting of Al, B, Ba, Be, Ca, Ce, Co, Cs, Dy, Er, Fe, Gd, Hf, Ho, La, Mg, Mn, Mo, Nb, Nd, Ni, Pr, Sc, Sm, Sr, Ta, V, W, Y, and Yb; the Zr being the majority element of the target.

86. The sputtering target of claim 85 wherein the Zr concentration within the target is at least 70%.

87. The sputtering target of claim 85 wherein the Zr concentration within the target is at least 90%.

88. The sputtering target of claim 85 wherein the Zr concentration within the target is at least 94%.

89. The sputtering target of claim 85 wherein the Zr concentration within the target is at least 97%.

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90. The sputtering target of claim 85 wherein the Zr concentration within the target is less than 98%.

91. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is in a range of from 0.001% to 50% of the ingot.

92. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is in a range of 0.001% to 10% of the ingot.

93. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is at least 0.01% of the ingot.

94. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is at least 0.1% of the ingot.

95. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is at least 1% of the ingot.

96. The sputtering target of claim 85 wherein the total non-zirconium metal content of the target is at least 2% of the ingot.

97. The sputtering target of claim 85 consisting of Zr and Ti.

98. A sputtering target comprising Zr and Ti; the Zr being the majority element of the target and being present to a concentration within the target of at least 55%.

99. The sputtering target of claim 98 wherein the Zr concentration within the target is at least 70%.

100. The sputtering target of claim 98 wherein the Zr concentration within the target is at least 90%.

101. The sputtering target of claim 98 wherein the Zr concentration within the target is at least 94%.

102. The sputtering target of claim 98 wherein the Zr concentration within the target is at least 97%.

103. The sputtering target of claim 98 wherein the Zr concentration within the target is less than 98%.

104. A sputtering target comprising Ti and B; the Ti being the majority element of the target.

105. The sputtering target of claim 104 wherein the Ti concentration within the target is at least 70%.

106. The sputtering target of claim 104 wherein the Ti concentration within the target is at least 90%.

107. The sputtering target of claim 104 wherein the Ti concentration within the target is at least 94%.

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108. The sputtering target of claim 104 wherein the Ti concentration within the target is at least 97%.

~~109. The sputtering target of claim 108 wherein the B content of the target is greater than 5 ppm.~~

110. The sputtering target of claim 108 wherein the B content of the target is greater than 50 ppm.

111. The sputtering target of claim 108 wherein the B content of the target is greater than 500 ppm.

112. The sputtering target of claim 108 wherein the B content of the target is greater than one part per thousand.

113. The sputtering target of claim 104 wherein the Ti concentration within the target is less than 98%.

114. The sputtering target of claim 104 wherein the B content of the target is greater than 5 ppm.

115. The sputtering target of claim 104 wherein the B content of the target is greater than 50 ppm.

116. The sputtering target of claim 104 wherein the B content of the target is greater than 500 ppm.

117. The sputtering target of claim 104 wherein the B content of the target is greater than one part per thousand.

118. The sputtering target of claim 104 consisting of Ti and B.

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